TESTS OF THE AERODYNE DUST COLLECTOR

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This presentation of the air cleaning program of the Aircraft Nuclear Propulsion Department of General Electric will be limited to recent tests of the Aerodyne dust collector.

Mechanical dust separators usually do not involve as great expense due to accumulated dust as do filters. The Aerodyne was a mechanical dust separator which was available for test and which appeared possible to operate at required efficiency in the 2 to 5 micron range of dust particle size. Previous tests on the Aerodyne had been made at dust concentrations of 0.5 grain per cubic foot and higher, as are encountered in usual dusty industrial processes. This information indicated an increase in efficiency with a decrease in dust concentration. No information was available at concentrations below 0.5 grain per cubic foot or with relatively high specific gravity of the dust material. This test was made to cover the range of dust concentration below 1/2 grain/CF. The efficiency of dust separation is dependent upon the size distribution of the test dust. To test the efficiency at small particle sizes, it is necessary to separate, from the test dust, the large agglomerates, which may contribute a large fraction of the mass. To permit comparison of results, the size distribution of the airborne dust must be determined.

The essential feature of the Aerodyne dust collector is a cone, shown in Slide 1; this cone is the primary separator, in which dust is concentrated toward the apex; the separation occurs when the air makes a sharp turn out through the louvres and the dust, having greater inertia keeps a straighter path, toward the apex. (Slide 2). About five percent of the total air flow, along with the separated dust passes out from the narrow section of the cone and is drawn through a two stage cyclone separator of conventional design. The cyclone effects final concentration of dust to solid material. The air from the cyclone goes through a blower necessary to maintain circulation in the secondary loop, and from the blower is returned to the duct above the inlet to the cone.

Most of the total air flow entered the test system through efficient paper filters; a small fraction was supplied by the jet.

The test dust was cupric oxide powder, of Merck or Baker & Adamson manufacture, technical or CP grade.

The dust was dispersed from the jet shown in Slide 3. The copper oxide agglomerates were transported to the jet where much of the agglomerated material was sheared into smaller particles. The dust feed system is shown in Slide 4.

The copper oxide was fed to the pneumatic transport tube at an adjustable rate by raising a hydraulic elevator. The elevator and copper oxide tube were in a pressurized container, built up from pipe, tubing, and fittings: the standard fittings are not detailed in the schematic drawings. Compressed air at about 90 psig was put through 2 parallel, porous, liquid entrainment separators and then through a depth of about 6 feet of 6-12 mesh silica gel to make the air unsaturated. This dried air was fed to the jet and to the pressurizing container for the feed tube. The flow through the pneumatic transport line was stabilized by a diaphragm pressure control and adjusted to maintain the copper oxide powder level in the supply tube about one inch below the inlet of the transport tube to the jet. Use of a plastic viewing window, glass supply tube and a small light permitted observation of the copper oxide level in the supply tube and indicated the uniformity of delivery to the transport tube. Feed rates yielding from .5 grain/cubic foot down to .0087 grain/cubic foot were used, at 2320 standard CFM total flow.

Some control of the particle size distribution for the larger particles was obtained by variation of the average residence time for air in the dust chamber, dependent upon the location of the partition, as shown in Slide 5.

Flow through the sampling filters was either limited by a critical pressure orifice or measured by a Fisher-Porter flowmeter with indicated rates reduced to standard pressure.

Total air flow was measured by the differential pressure across the standard flow nozzle. Readings were corrected for barometric pressure and temperature. The average of 20 values is given; the maximum deviation from the average was 2%. Manometers were also used to check pressure differentials across the large filters, across the blowers, and at several other points of the flow system.

The efficiency of dust separation was obtained by weighing the dust collected in the Aerodyne dust chamber and taking the ratio of this to the amount delivered to the Aerodyne; the amount delivered is the difference between the total amount fed to the jet and the amount that settles out in the large dust chamber. The amount settling out was determined by careful cleaning of the large dust chamber with a "Filter Queen" brand vacuum cleaner. With this cleaner it is possible to weigh the filter and collected dust separately from the rest of the cleaner so that accuracy to one thirtieth (1/30) of one ounce is possible. The same method was used to get the weight of CuO in the dust collection chamber of the Aerodyne Unit.

The Aerodyne Unit as supplied by the manufacturer gave separation efficiencies around 41%, due to partial flow through a pipe from the dust concentrate line to the main blower, (Slide 2). When this opening was plugged and reasonable flow established in the secondary flow circuit by increasing the secondary blower speed by 33% to give .3 inch water lower pressure in the cone exit than in the cone chamber, the dust removal efficiency was increased to the values given in the abstract, 62 to 79%, depending upon dust concentration.

The airborne dust particle size distribution was obtained by examination of a typical area of a "Millipore" analytical filter, upon which a sample of the dust was deposited.

The dust particles were compared in size with circular areas on an eyepiece reticle, made by Kodak, Ltd. The comparison areas increased geometrically, each being twice the next smaller one. The parameter M, Slide 6, is the index number of the areas, and corresponds with the micron scale when the oil immersion, 95X objective was used, with 15X eyepiece. Other magnifications were used to increase the statistical accuracy for larger particles, but the data at high magnification is required to provide the distribution at small sizes. Use of the 3 magnifications and reduction of data to equivalent 95X conditions leads to some non integral values of M. All data are normalized to the same total area, corresponding to 30,300 reticle fields with the 95X objective; the data plotted indicate the overlapping ranges of size observed at the 3 magnifications used. The particle distribution by number, $\frac{\Delta N}{\Delta M}$, as graphically averaged, was multiplied by the particle volume and normalized to give the mass distribution:

$$51.5 \ D^3 \left(\frac{\Delta N}{\Delta M}\right)$$

The mass median was obtained by numerical integration of the mass distribution, giving the value 4.3 microns; the mass median size is indicated.

The overall efficiency* of the Aerodyne, E, is in terms of the separate average efficiencies of the cone, E_1, and of the cyclone, E_2:

$$E = \frac{E_1E_2}{1 - E_1(1-E_2)}$$

This relation follows from the steady state condition for the mass of dust recycled per second, K, in terms of the efficiencies E_1 and E_2 and the dust mass fed to the system per second, M:

$$K = (K + M) \quad E_1 \ (1-E_2)$$

Here K + M is the dust load per second entering the Aerodyne cone, E_1 the average efficiency of the cone, not for the primary dust, but for the combined distribution of primary feed M and recycled dust K; this combined dust tends to smaller average particle size than the primary dust because the cyclone separation efficiency is higher for larger particles; however, a competing effect, the higher efficiency of the cone for larger particles, tends to increase the size of the recycle dust compared to primary. The cyclone efficiency, E_2, similarly applies to K + M, the combined

* Derived by C. C. Gamertsfelder, private communication.

distribution, but miltiplied by the separation efficiency, a function of partial size, for the cone.

To investigate the influence of the cyclones upon the efficiency of the Aerodyne, the cyclone unit was replaced for one run by 4 two inch thick American Air Filter "Amerglas" filter units in series, as indicated by the dotted squares in Slide 2.

With other conditions the same as when the overall efficiency of 69% was obtained with the cyclones as dust collectors, with the filters an overall efficiency of 73% was obtained. The amounts recovered on the successive filters were 271, 53.3, 10.7 and 4.0 grams, indicating that the first filter removed 78%. The amounts collected on each filter are plotted (Slide 7) and if the curve is extrapolated to estimate the efficiency of the four filters by comparison with an infinitely thick filter, then the efficiency of the four filter units used was 98%. This indicated that the Aerodyne cone efficiency was about 73% at this dust concentration; recycling in the secondary flow circuit is here unimportant since the small sizes passed by the four filters are passed with high probability by the Aerodyne cone.

If the cone efficiency of 73% is used with the overall Aerodyne efficiency of 69% (all at .1 grain/cubic foot), and if the efficiency for the combined recycle and primary dust is assumed the same as for the primary dust, the calculated cyclone efficiency for the combined dust is 82%.

The efficiency relation gives useful and possibly unexpected results:

E_1 (primary)	E_2 (secondary)	E (overall)
50	100	50
100	50	100

These values indicate that the primary efficiency E_1 is (if both E_1 and E_2 are tolerably good) much more important.

The Aerodyne Test Results are tabulated:

Weights of CuO, grams:

To Jet	Settled in Dust Chamber	Delivered to Aerodyne	Collected by Aerodyne	Collection Efficiency %	Dust Concentration grains/ cubic foot
820.0	461.6	358.4	222.3	62	.49
614	248	366	252	69	.112
710	231	479	349*	73*	.112*
621	281	340	269	79	.0087

* Filters replaced cyclones.

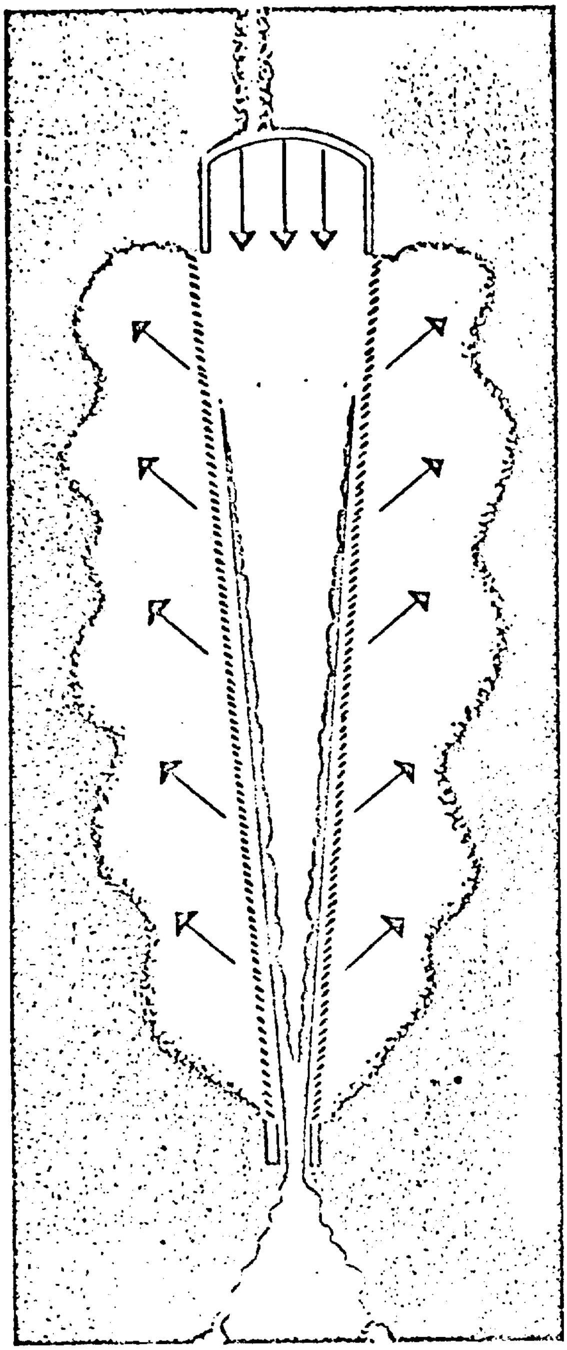
ACCURACY:

Weights were accurate to 1% or to one gram, the larger being applicable. The collection efficiency accuracy is 1%. The particle size distribution by number has statistical accuracies of 10% from .3 micron to 5 microns, 17% at 6 microns and 30% at 8.5 microns; no particles larger than 9 microns were found.

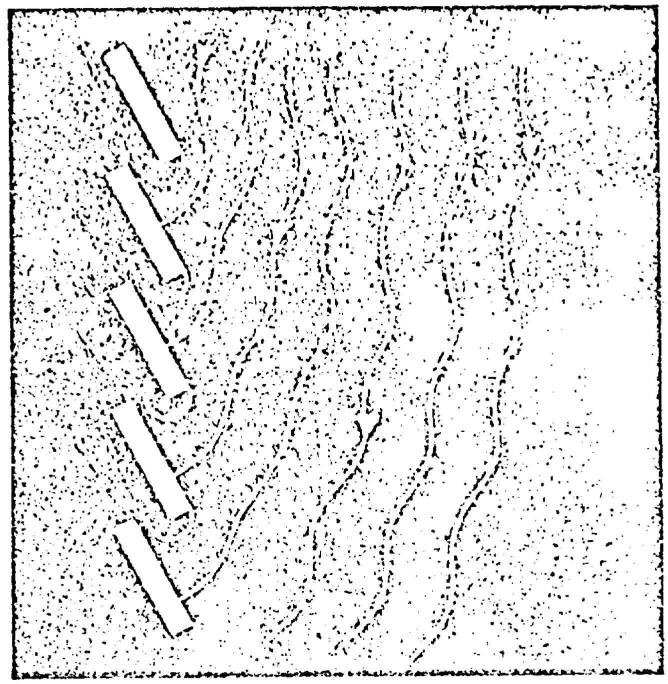
Systematic variation from one magnification used in counting particles, to another magnification displaced the corresponding points of the distribution by slightly more than $\Delta M = 1/2$. Each particle was assigned to a group within $\Delta M = 1/2$. The perceptible dispersion of the experimental points of Slide 6 is due primarily to the difficulty in classification by group index M, even though eleven groups were used. This source of error is larger for smaller numbers of groups. The mass median, 4.3, microns, is accurate to one micron, limited by experimental uncertainty in the distribution.

To summarize, the efficiency of an Aerodyne Dust Collector was determined as a function of dust concentration, for values below 1 grain/cubic foot. Copper oxide powder was the test dust, with an experimentally determined mass median of 4.3 microns and with no particles observed above 9 microns. The efficiencies obtained were:

Approximate Dust Concentration	Weight Efficiency
.5 grain/cubic foot	62%
.1 grain/cubic foot	69%
.01 grain/cubic foot	79%

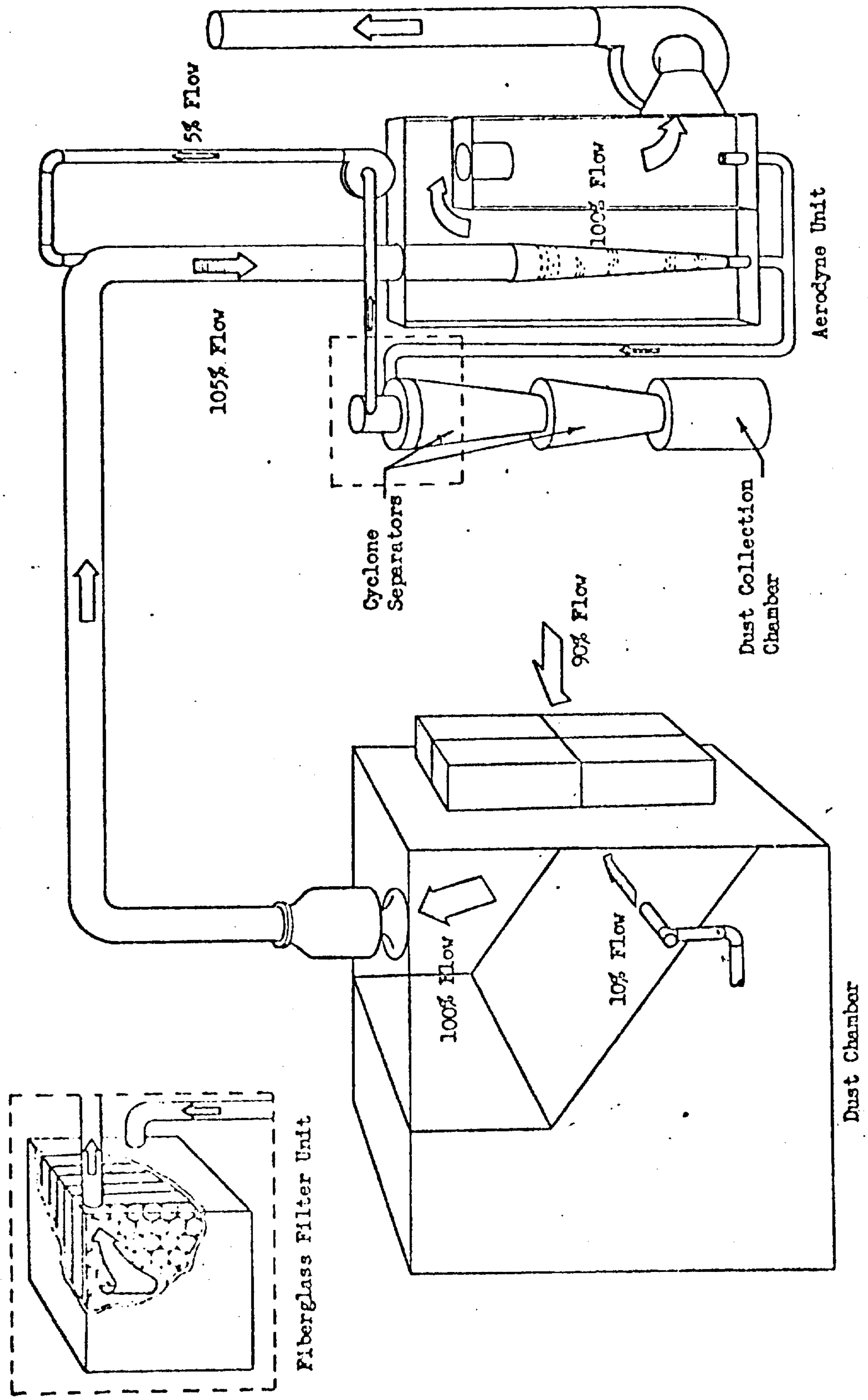


AERODYNE CONE FLOW AND
DUST SEPARATION

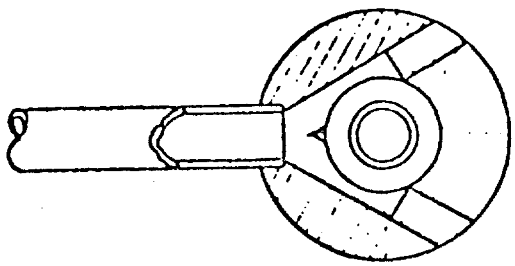


LOUVRE FLOW DETAIL

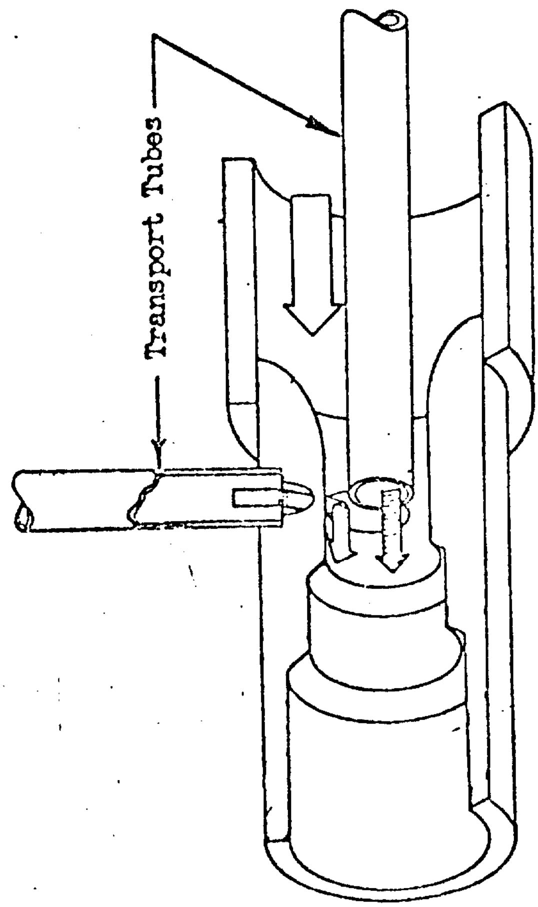
SLIDE 1



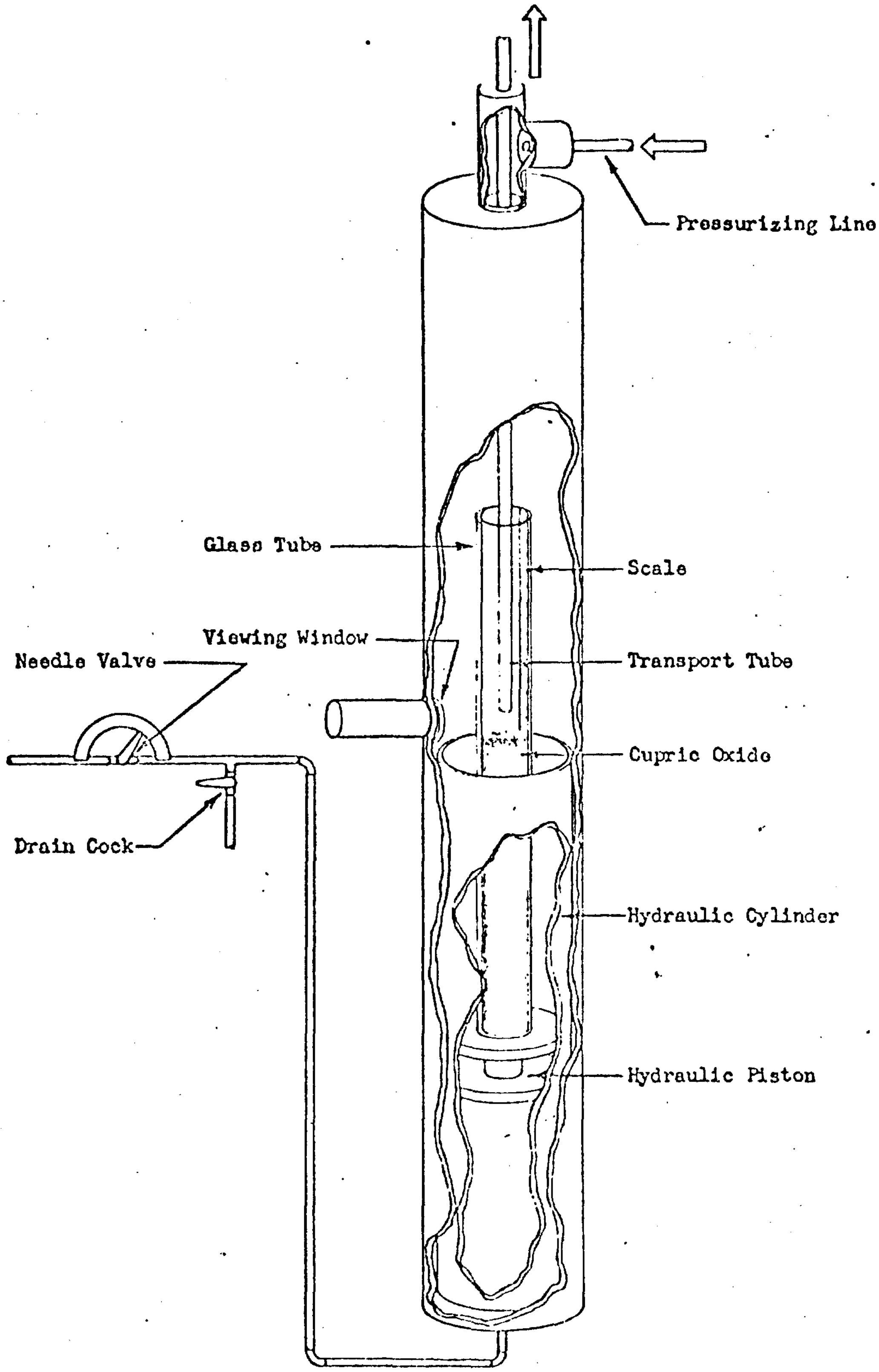
Slide 2. MAIN FLOW SHEET



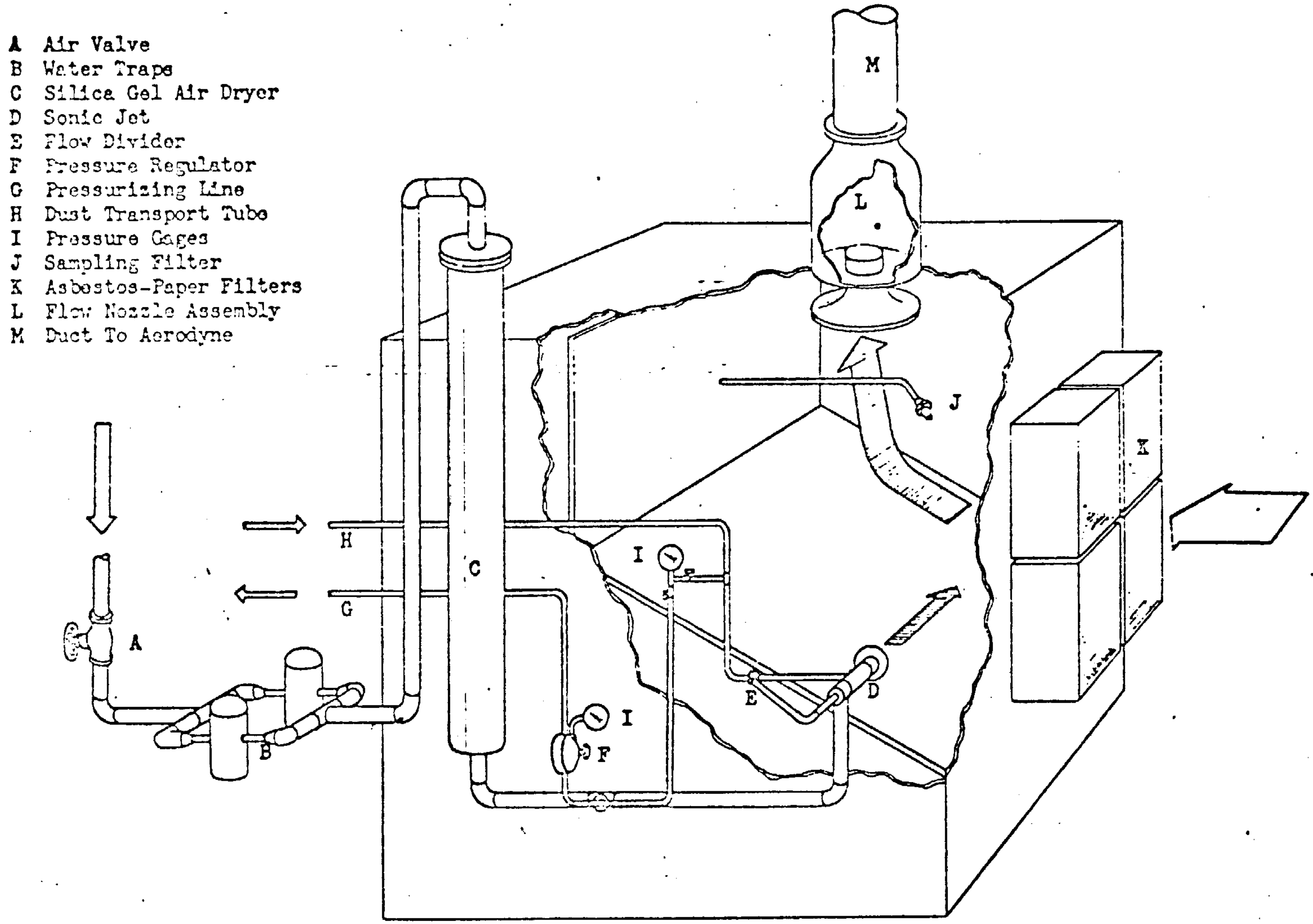
Throat Section



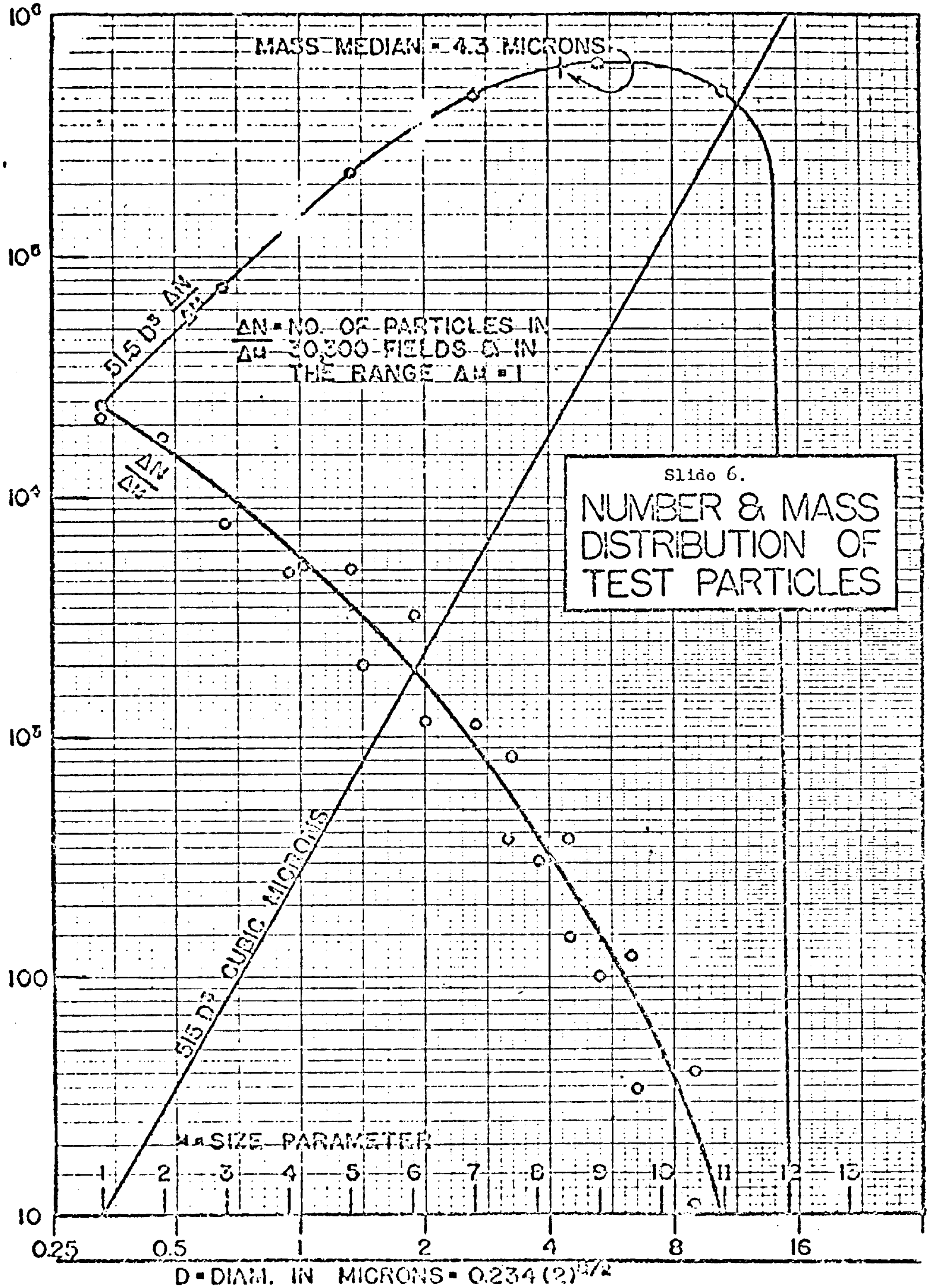
Slide 3. DUST GENERATOR SONIC JET

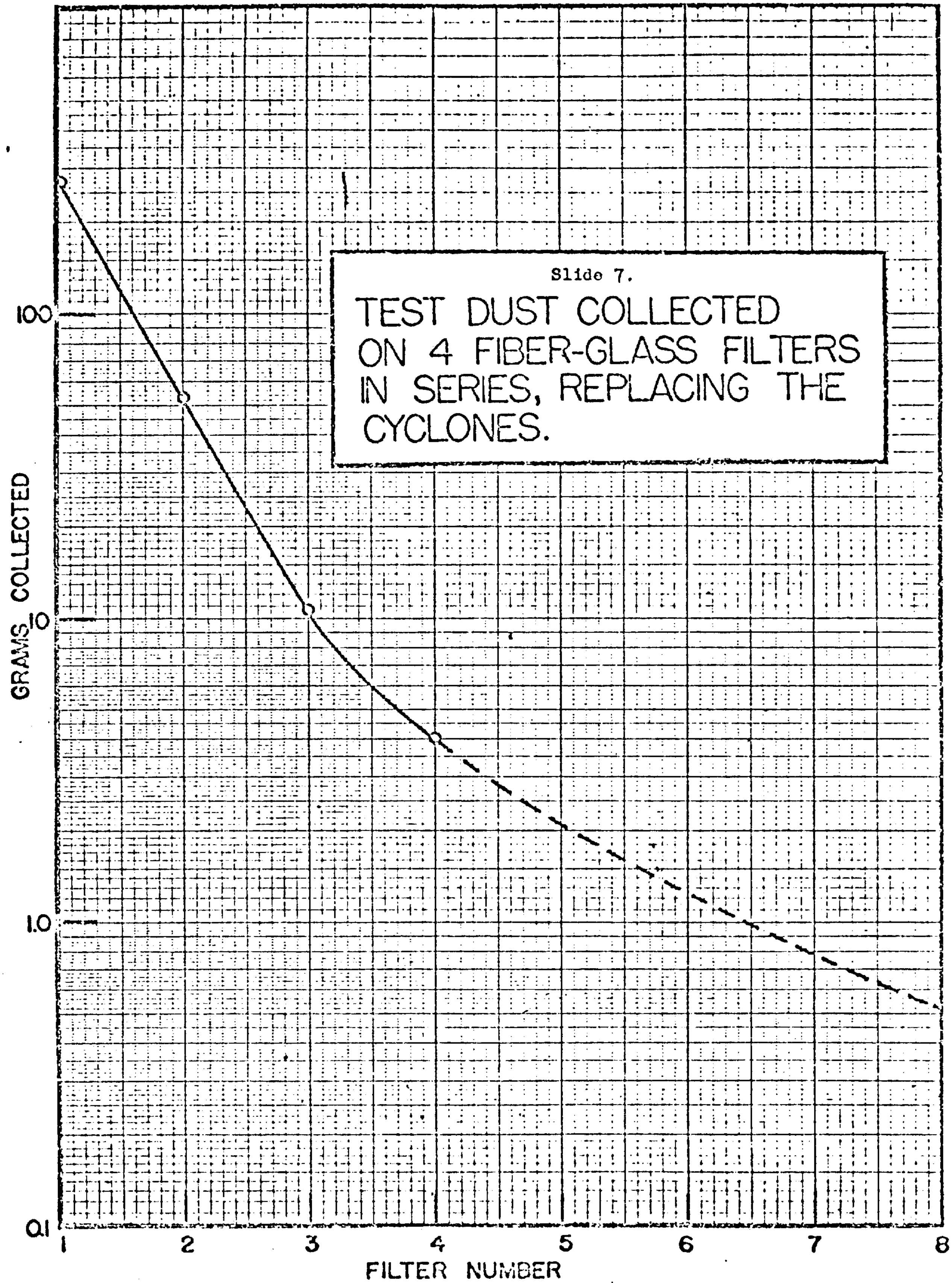


Slide 4. DUST GENERATOR VARIABLE FEED UNIT



Slide 5. DUST CHAMBER AND AUXILIARIES


MASS MEDIAN = 4.3 MICRONS
ΔN = NO. OF PARTICLES IN
Δu 30,300 FIELDS & IN
THE RANGE Δu = 1
$515 D^3 \frac{\Delta N}{\Delta u}$
$\frac{\Delta N}{\Delta u}$
$515 D^3$ CUBIC MICRONS
u = SIZE PARAMETER
Slide 6.
NUMBER & MASS
DISTRIBUTION OF
TEST PARTICLES
D = DIAM. IN MICRONS = $0.234 (2)^{u/2}$


Slide 7.
TEST DUST COLLECTED ON 4 FIBER-GLASS FILTERS IN SERIES, REPLACING THE CYCLONES.
GRAMS COLLECTED
100
10
1.0
0.1
1
2
3
4
5
6
7
8
FILTER NUMBER